

## References

- Abe, H., Takeshita, T., Nagata, K., Arita, T., Endo, Y., Fujita, T., Takayama, H., Kubo, M. and Sugamura, K. (1999) Molecular cloning, chromosome mapping and characterization of the mouse CRTH2 gene, a putative member of the leukocyte chemoattractant receptor family. *Gene*, 227, 71-77.
- Abou-Haila, A. and Tulsiani, D.R. (2000) Mammalian sperm acrosome: formation, contents, and function. *Arch Biochem Biophys*, 379, 173-182.
- Akatsuka, K., Yoshida-Komiya, H., Tulsiani, D.R., Orgebin-Crist, M.C., Hiroi, M. and Araki, Y. (1998) Rat zona pellucida glycoproteins: molecular cloning and characterization of the three major components. *Mol Reprod Dev*, 51, 454-467.
- Bause, E., Bieberich, E., Rolfs, A., Volker, C. and Schmidt, B. (1993) Molecular cloning and primary structure of Man9-mannosidase from human kidney. *Eur J Biochem*, 217, 535-540.
- Benoff, S. (1997) Carbohydrates and fertilization: an overview. *Mol Hum Reprod*, 3, 599-637.
- Benoff, S., Barcia, M., Hurley, I.R., Cooper, G.W., Mandel, F.S.,

- Heyner, S., Garside, W.T., Gilbert, B.R. and Hershlag, A. (1996) Classification of male factor infertility relevant to in-vitro fertilization insemination strategies using mannose ligands, acrosome status and anti-cytoskeletal antibodies. *Hum Reprod*, 11, 1905–1918.
- Benoff, S., Cooper, G.W., Hurley, I., Napolitano, B., Rosenfeld, D.L., Scholl, G.M. and Hershlag, A. (1993a) Human sperm fertilizing potential in vitro is correlated with differential expression of a head-specific mannose-ligand receptor. *Fertil Steril*, 59, 854–862.
- Benoff, S., Hurley, I., Cooper, G.W., Mandel, F.S., Hershlag, A., Scholl, G.M. and Rosenfeld, D.L. (1993b) Fertilization potential in vitro is correlated with head-specific mannose-ligand receptor expression, acrosome status and membrane cholesterol content. *Hum Reprod*, 8, 2155–2166.
- Benoff, S., Hurley, I., Cooper, G.W., Mandel, F.S., Rosenfeld, D.L. and Hershlag, A. (1993c) Head-specific mannose-ligand receptor expression in human spermatozoa is dependent on capacitation-associated membrane cholesterol loss. *Hum Reprod*, 8, 2141–2154.
- Benoff, S., Hurley, I.R., Mandel, F.S., Cooper, G.W. and Hershlag, A. (1997a) Induction of the human sperm acrosome reaction with mannose-containing neoglycoprotein ligands. *Mol Hum Reprod*, 3, 827–837.
- Benoff, S., Hurley, I.R., Mandel, F.S., Paine, T., Jacob, A.,

Cooper, G.W. and Hershlag, A. (1997b) Use of mannose ligands in IVF screens to mimic zona pellucida-induced acrosome reactions and predict fertilization success. *Mol Hum Reprod*, 3, 839-846.

Bischoff, J., Moremen, K. and Lodish, H.F. (1990) Isolation, characterization, and expression of cDNA encoding a rat liver endoplasmic reticulum alpha-mannosidase. *J Biol Chem*, 265, 17110-17117.

Boettger-Tong, H.L., Aarons, D.J., Biegler, B.E., George, B. and Poirier, G.R. (1993) Binding of a murine proteinase inhibitor to the acrosome region of the human sperm head. *Mol Reprod Dev*, 36, 346-353.

Bookbinder, L.H., Cheng, A. and Bleil, J.D. (1995) Tissue- and species-specific expression of sp56, a mouse sperm fertilization protein [see comments] [published erratum appears in Science 1995 Aug 25;269(5227):1120]. *Science*, 269, 86-89.

Brown, C.R., von Glos, K.I. and Jones, R. (1983) Changes in plasma membrane glycoproteins of rat spermatozoa during maturation in the epididymis. *J Cell Biol*, 96, 256-264.

Camirand, A., Heysen, A., Grondin, B. and Herscovics, A. (1991) Glycoprotein biosynthesis in *Saccharomyces cerevisiae*. Isolation and characterization of the gene encoding a specific processing alpha-mannosidase. *J Biol Chem*, 266, 15120-15127.

- Chayko, C.A., Orgebin-Crist, M.C., Skudlarek, M.D. and Tulsiani, D.R. (2000) Biosynthesis, processing, and subcellular localization of rat sperm beta-D-galactosidase [In Process Citation]. *Biol Reprod*, 63, 688-696.
- Cheng, A., Le, T., Palacios, M., Bookbinder, L.H., Wassarman, P.M., Suzuki, F. and Bleil, J.D. (1994) Sperm-egg recognition in the mouse: characterization of sp56, a sperm protein having specific affinity for ZP3. *J Cell Biol*, 125, 867-878.
- Cornwall, G.A., Tulsiani, D.R. and Orgebin-Crist, M.C. (1991) Inhibition of the mouse sperm surface alpha-D-mannosidase inhibits sperm-egg binding in vitro. *Biol Reprod*, 44, 913-921.
- Dacheux, J.L., Druart, X., Foucheau, S., Syntin, P., Gatti, J.L., Okamura, N. and Dacheux, F. (1998) Role of epididymal secretory proteins in sperm maturation with particular reference to the boar. *J Reprod Fertil Suppl*, 53, 99-107.
- Eccleston, E.D., White, T.W., Howard, J.B. and Hamilton, D.W. (1994) Characterization of a cell surface glycoprotein associated with maturation of rat spermatozoa. *Mol Reprod Dev*, 37, 110-119.
- Fawcett, D.W., Eddy, E.M. and Phillips, D.M. (1970) Observations on the fine structure and relationships of the chromatoid body in mammalian spermatogenesis. *Biol Reprod*, 2, 129-153.
- Flanagan, K., Scouten, W.H. and Nyquist, S.E. (1982)

Involvement of dolichol phosphates as intermediates in the mannosyl and galactosyl transferases of rat testicular germ cell Golgi apparatus membranes. *Biol Reprod*, 26, 147–154.

Foster, J.A., Friday, B.B., Maulit, M.T., Blobel, C., Winfrey, V.P., Olson, G.E., Kim, K.S. and Gerton, G.L. (1997) AM67, a secretory component of the guinea pig sperm acrosomal matrix, is related to mouse sperm protein sp56 and the complement component 4-binding proteins. *J Biol Chem*, 272, 12714–12722.

Garberi, J.C., Fontana, J.D. and Blaquier, J.A. (1982) Carbohydrate composition of specific rat epididymal protein. *Int J Androl*, 5, 619–626.

Goluboff, E.T., Mertz, J.R., Tres, L.L. and Kierszenbaum, A.L. (1995) Galactosyl receptor in human testis and sperm is antigenically related to the minor C-type (Ca(2+)-dependent) lectin variant of human and rat liver. *Mol Reprod Dev*, 40, 460–466.

Hamilton, D.W., Wenstrom, J.C. and Baker, J.B. (1986) Membrane glycoproteins from spermatozoa: partial characterization of an integral Mr = approximately 24,000 molecule from rat spermatozoa that is glycosylated during epididymal maturation. *Biol Reprod*, 34, 925–936.

Jayakumar, P.G., Arunakaran, J., Aruldas, M.M. and Govindarajulu, P. (1992) Role of prolactin on epididymal glycoprotein metabolism in matured monkeys, *Macaca radiata*: specific activities of

- glycosyltransferases and glycosidases. *Indian J Exp Biol*, 30, 1075–1078.
- Jin, Y.Z., Bannai, S., Dacheux, F., Dacheux, J.L. and Okamura, N. (1997) Direct evidence for the secretion of lactoferrin and its binding to sperm in the porcine epididymis. *Mol Reprod Dev*, 47, 490–496.
- Jin, Y.Z., Dacheux, F., Dacheux, J.L., Bannai, S., Sugita, Y. and Okamura, N. (1999) Purification and properties of major alpha-D-mannosidase in the luminal fluid of porcine epididymis. *Biochim Biophys Acta*, 1432, 382–392.
- Johnston, D.S., Shaper, J.H., Shaper, N.L., Joziasse, D.H. and Wright, W.W. (1995) The gene encoding murine alpha 1,3-galactosyltransferase is expressed in female germ cells but not in male germ cells. *Dev Biol*, 171, 224–232.
- Jones, R. and Brown, C.R. (1982) Association of epididymal secretory proteins showing alpha-lactalbumin-like activity with the plasma membrane of rat spermatozoa. *Biochem J*, 206, 161–164.
- Jones, R. and Brown, C.R. (1987) Identification and characterization of the 2D6 and Mr 23,000 antigens on the plasma membrane of rat spermatozoa. *Biochem J*, 241, 353–360.
- Jones, R., Brown, C.R., von Glos, K.I. and Gaunt, S.J. (1985) Development of a maturation antigen on the plasma membrane of rat spermatozoa in the epididymis and its fate during fertilization. *Exp Cell Res*, 156, 31–44.

Jones, R., Pholpramool, C., Setchell, B.P. and Brown, C.R. (1981) Labelling of membrane glycoproteins on rat spermatozoa collected from different regions of the epididymis. *Biochem J*, 200, 457-460.

Jones, R., von Glos, K.I. and Brown, C.R. (1983) Changes in the protein composition of rat spermatozoa during maturation in the epididymis. *J Reprod Fertil*, 67, 299-306.

Kozak, M. (1984) Compilation and analysis of sequences upstream from the translational start site in eukaryotic mRNAs. *Nucleic Acids Res*, 12, 857-872.

Loeser, C.R., Lynch, C., 2nd and Tulsiani, D.R. (1999) Characterization of the pharmacological-sensitivity profile of neoglycoprotein-induced acrosome reaction in mouse spermatozoa. *Biol Reprod*, 61, 629-634.

Loeser, C.R. and Tulsiani, D.R. (1999) The role of carbohydrates in the induction of the acrosome reaction in mouse spermatozoa. *Biol Reprod*, 60, 94-101.

Mertz, J.R., Banda, P.W. and Kierszenbaum, A.L. (1995) Rat sperm galactosyl receptor: purification and identification by polyclonal antibodies raised against multiple antigen peptides. *Mol Reprod Dev*, 41, 374-383.

Monesi, V. (1964) Autoradiographic study of DNA synthesis and the cell

cycle in spermatogonia and spermatocytes of mouse testis using tritiated thymidine. *j of Cell Biology*, 14, 1-18.

Moore, A., White, T.W., Ensrud, K.M. and Hamilton, D.W. (1989) The major maturation glycoprotein found on rat cauda epididymal sperm surface is linked to the membrane via phosphatidylinositol. *Biochem Biophys Res Commun*, 160, 460-468.

Moremen, K.W. and Robbins, P.W. (1991) Isolation, characterization, and expression of cDNAs encoding murine alpha-mannosidase II, a Golgi enzyme that controls conversion of high mannose to complex N-glycans. *J Cell Biol*, 115, 1521-1534.

Mortillo, S. and Wassarman, P.M. (1991) Differential binding of gold-labeled zona pellucida glycoproteins mZP2 and mZP3 to mouse sperm membrane compartments. *Development*, 113, 141-149.

Moussa, F., Oko, R. and Hermo, L. (1994) The immunolocalization of small nuclear ribonucleoprotein particles in testicular cells during the cycle of the seminiferous epithelium of the adult rat. *Cell Tissue Res*, 278, 363-378.

Nagdas, S.K., Skudlarek, M.D., Orgebin-Crist, M.C. and Tulsiani, D.R. (1992) Biochemical alterations in the proacrosin-acrosin system during epididymal maturation of the rat spermatozoa. *J Androl*, 13, 36-43.

Noguchi, J., Hikono, H., Sato, S., Watanabe, G., Taya, K.,

Sasamoto, S. and Hasegawa, Y. (1997) Ontogeny of inhibin secretion in the rat testis: secretion of inhibin-related proteins from fetal Leydig cells and of bioactive inhibin from Sertoli cells. *J Endocrinol*, 155, 27–34.

Ohata, K., Okamura, N., Kojima, M. and Yasue, H. (1997) Assignment of alpha-mannosidase gene (MAN2B2) to swine chromosome 8p23–pter by fluorescence in situ hybridization. *Mamm Genome*, 8, 158–159.

Okamura, N., Dacheux, F., Venien, A., Onoe, S., Huet, J.C. and Dacheux, J.L. (1992) Localization of a maturation-dependent epididymal sperm surface antigen recognized by a monoclonal antibody raised against a 135-kilodalton protein in porcine epididymal fluid. *Biol Reprod*, 47, 1040–1052.

Okamura, N., Tajima, Y. and Sugita, Y. (1988) Decrease in bicarbonate transport activities during epididymal maturation of porcine sperm. *Biochem Biophys Res Commun*, 157, 1280–1287.

Okamura, N., Tamba, M., Liao, H.J., Onoe, S., Sugita, Y., Dacheux, F. and Dacheux, J.L. (1995) Cloning of complementary DNA encoding a 135-kilodalton protein secreted from porcine corpus epididymis and its identification as an epididymis-specific alpha-mannosidase. *Mol Reprod Dev*, 42, 141–148.

Oko, R., Korley, R., Murray, M.T., Hecht, N.B. and Hermo, L.

(1996) Germ cell-specific DNA and RNA binding proteins p48/52 are expressed at specific stages of male germ cell development and are present in the chromatoid body. *Mol Reprod Dev*, 44, 1-13.

Olson, G.E. and Hamilton, D.W. (1978) Characterization of the surface glycoproteins of rat spermatozoa. *Biol Reprod*, 19, 26-35.

Pereira, B.M., Abou-Haila, A. and Tulsiani, D.R. (1998) Rat sperm surface mannosidase is first expressed on the plasma membrane of testicular germ cells. *Biol Reprod*, 59, 1288-1295.

Poirier, G.R. (1975) Fine structure distribution of non-specific acid phosphatase in the head region of mouse spermatozoa from various regions of the male reproductive tract. *J Reprod Fertil*, 43, 495-499.

Quinn, P., Kerin, J.F. and Warnes, G.M. (1985) Improved pregnancy rate in human in vitro fertilization with the use of a medium based on the composition of human tubal fluid. *Fertil Steril*, 44, 493-498.

Ram, P.A., Cardullo, R.A. and Millette, C.F. (1989) Expression and topographical localization of cell surface fucosyltransferase activity during epididymal sperm maturation in the mouse. *Gamete Res*, 22, 321-332.

Revah, I., Gadella, B.M., Flesch, F.M., Colenbrander, B. and Suarez, S.S. (2000) Physiological state of bull sperm affects fucose- and mannose-binding properties. *Biol Reprod*, 62, 1010-1015.

Rivkin, E., Tres, L.L., Kaplan-Kraicer, R., Shalgi, R. and

- Kierszenbaum, A.L. (2000) Molecular cloning of rat sperm galactosyl receptor, a C-type lectin with in vitro egg binding activity. *Mol Reprod Dev*, 56, 401-411.
- Russell, L., Ettlin, R., Sinhahikim, A. and Clegg, E. (1990) Histological and histopathological evaluation of the testis. *Cache River Press*.
- Saling, P.M. (1981) Involvement of trypsin-like activity in binding of mouse spermatozoa to zonae pellucidae. *Proc Natl Acad Sci U S A*, 78, 6231-6235.
- Shalgi, R., Matityahu, A. and Nebel, L. (1986) The role of carbohydrates in sperm-egg interaction in rats. *Biol Reprod*, 34, 446-452.
- Shalgi, R. and Raz, T. (1997) The role of carbohydrate residues in mammalian fertilization. *Histol Histopathol*, 12, 813-822.
- Shur, B.D., Evans, S. and Lu, Q. (1998) Cell surface galactosyltransferase: current issues. *Glycoconj J*, 15, 537-548.
- Shur, B.D. and Hall, N.G. (1982) A role for mouse sperm surface galactosyltransferase in sperm binding to the egg zona pellucida. *J Cell Biol*, 95, 574-579.
- Sinowatz, F., Plendl, J. and Kolle, S. (1998) Protein-carbohydrate interactions during fertilization. *Acta Anat*, 161, 196-205.
- Skudlarek, M.D., Tulsiani, D.R., Nagdas, S.K. and Orgebin-Crist, M.C. (1993) Beta-D-galactosidase of rat spermatozoa: subcellular

distribution, substrate specificity, and molecular changes during epididymal maturation. *Biol Reprod*, 49, 204–213.

高橋道人、(1994) 精巢毒性評価のための精細管アトラス -ラット、マウス、イヌ-、ソフトサイエンス社。

Tanphaichitr, N., Smith, J., Mongkolsirikieart, S., Gradil, C. and Lingwood, C.A. (1993) Role of a gamete-specific sulfoglycolipid immobilizing protein on mouse sperm-egg binding. *Dev Biol*, 156, 164–175.

Tanphaichitr, N., Tayabali, A., Gradil, C., Juneja, S., Leveille, M.C. and Lingwood, C.A. (1992) Role of a germ cell-specific sulfolipid-immobilizing protein (SLIP1) in mouse *in vivo* fertilization. *Mol Reprod Dev*, 32, 17–22.

Tsunekawa, N., Matsumoto, M., Tone, S., Nishida, T. and Fujimoto, H. (1999) The Hsp70 homolog gene, Hsc70t, is expressed under translational control during mouse spermiogenesis. *Mol Reprod Dev*, 52, 383–391.

Tulsiani, D.R., Chayko, C.A., Orgebin-Crist, M.C. and Araki, Y. (1996) Temporal surge of glycosyltransferase activities in the genital tract of the hamster during the estrous cycle. *Biol Reprod*, 54, 1032–1037.

Tulsiani, D.R., Nagdas, S.K., Cornwall, G.A. and Orgebin-Crist, M.C. (1992) Evidence for the presence of high-mannose/hybrid oligosaccharide chain(s) on the mouse ZP2 and ZP3. *Biol Reprod*, 46, 93–

100.

Tulsiani, D.R., NagDas, S.K., Skudlarek, M.D. and Orgebin-Crist, M.C. (1995a) Rat sperm plasma membrane mannosidase: localization and evidence for proteolytic processing during epididymal maturation. *Dev Biol*, 167, 584-595.

Tulsiani, D.R., Skudlarek, M.D., Araki, Y. and Orgebin-Crist, M.C. (1995b) Purification and characterization of two forms of beta-D-galactosidase from rat epididymal luminal fluid: evidence for their role in the modification of sperm plasma membrane glycoprotein(s). *Biochem J*, 305, 41-50.

Tulsiani, D.R., Skudlarek, M.D., Holland, M.K. and Orgebin-Crist, M.C. (1993a) Glycosylation of rat sperm plasma membrane during epididymal maturation. *Biol Reprod*, 48, 417-428.

Tulsiani, D.R., Skudlarek, M.D., Nagdas, S.K. and Orgebin-Crist, M.C. (1993b) Purification and characterization of rat epididymal-fluid alpha-D- mannosidase: similarities to sperm plasma-membrane alpha-D-mannosidase. *Biochem J*, 290, 427-436.

Tulsiani, D.R., Skudlarek, M.D. and Orgebin-Crist, M.C. (1989) Novel alpha-D-mannosidase of rat sperm plasma membranes: characterization and potential role in sperm-egg interactions. *J Cell Biol*, 109, 1257-1267.

Tulsiani, D.R., Skudlarek, M.D. and Orgebin-Crist, M.C. (1990a)

Human sperm plasma membranes possess alpha-D-mannosidase activity but no galactosyltransferase activity. *Biol Reprod*, 42, 843–858.

Tulsiani, D.R., Skudlarek, M.D. and Orgebin-Crist, M.C. (1990b) Swainsonine induces the production of hybrid glycoproteins and accumulation of oligosaccharides in male reproductive tissues of the rat. *Biol Reprod*, 43, 130–138.

Tulsiani, D.R., Yoshida-Komiya, H. and Araki, Y. (1997) Mammalian fertilization: a carbohydrate-mediated event. *Biol Reprod*, 57, 487–494.

Yoshida-Komiya, H., Tulsiani, D.R., Hirayama, T. and Araki, Y. (1999) Mannose-binding molecules of rat spermatozoa and sperm-egg interaction. *Zygote*, 7, 335–346.

## Acknowledgement

I thank Professor Shiro Bannai, assistant professor Tetsuro Ishii, instructor, Hideyo Sato and Professor Naomichi Okamura for their kind help, guidance and encouragement during the course of this study and preparation of this doctoral dissertation.

I thank Dr. Takehiko Koji for his useful suggestions on *In situ* hybridization. I thank Dr. Junko Noguchi for her useful suggestions on Immunohistochemistry. I thank Dr. Nakajima for his useful suggestions on *In vitro* fertilization assay. I thank Dr. Yuichi Endo for his useful suggestions on Chromosome mapping.

I also express my appreciation to my all colleagues Michiko Tamba, Dr. Yin-Zhe Jin, Sachiko Kiuchi, Takayuki Kashima, Misachi Araki, Miho Kanno.

Finally, I am grateful to all experimental animals in this study.